In re Patent Application of:
DOUGHERTY ET AL
Serial No. **10/629,143**
Filed: **JULY 29, 2003**

REMARKS

Prior to the present amendment, claims 1-4 were pending. As a result of the foregoing amendments, which include the addition of new claims 5-9, claims 1-9 are currently pending. Reconsideration of this application in light of the foregoing amendments and following remarks is respectfully requested.

The courtesies extended by supervisory Examiner Bovernik on June 20, 2006, and those extended by Examiner Pak, during discussions with applicants' attorney, on July 5, 2006, are gratefully appreciated. As pointed out by the undersigned during these discussions, Applicants have amended claims 1-4 in an effort to more particularly define the fact that the present invention employs a waveguide bend having a size and shape that cause a polarization-dependent loss therethrough that is <u>opposite</u> to that of the coupling structure upstream of the bend, so as to <u>compensate</u> for the polarization-dependent loss through the coupling portion. New dependent claims 5-8 specify particular parameters of the bend, while new claim 9 defines a method for compensating for the polarization-dependent loss through the coupling, by the use of a bend downstream thereof, the bend again having a size and shape that impart a compensating polarization-dependent loss that is opposite to that of the coupling portion.

It is respectfully submitted that such a polarization-dependent loss compensating structure and method are not disclosed or suggested by the prior art cited in the outstanding Office Action. Consequently, the rejection of claims 1-4 under 35 U.S.C. § 103(a), particularly as applied to amended claims 1-4 and new claims 5-9, as being unpatentable over Hsu et al (U.S. Patent 6,885,795 B1), and further in view of Rajarajan et al (IEEE, Novel Polarization-Independent Optical Bends For Compact Photonic Integrated Circuits, previously applied upon), is respectfully traversed. The deficiencies of the prior art relied upon in the rejection will be discussed below with reference to each claim.

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Claim 1

Claim 1 specifies, *inter alia*, a planar optical waveguide tap, comprising:

1 - a first optical waveguide supporting a first polarization mode and a second polarization mode;

2 - a second optical waveguide having a coupling portion for receiving a portion of light launched into the first optical waveguide, and coupling light in a first, substantially polarization-dependent manner, *so that light of the second polarization experiences higher optical loss through said coupling portion than light of said first polarization mode*; and

3 - a bend portion of the second optical waveguide having at least one ***predetermined bend*** therein having a size and shape that are effective to cause light to be transmitted through said bend portion in a second, substantially polarization-dependent manner, that is opposite to said first, substantially polarization-dependent manner, so that the second polarization mode couples through the bend portion significantly more strongly than the first polarization, whereby light of the first polarization mode experiences higher optical loss in the bend than light of the second polarization mode, *so as* ***to substantially compensate*** *for a polarization-dependent loss that occurs from the coupling portion* . (Emphasis Added)

The newly cited patent to **Hsu et al** 6,885,795, discloses a waveguide tap monitor that includes a first (primary) waveguide (16), and a second (tap) waveguide (12), which receives a portion of light propagating in the primary waveguide. A direction changing region (14) directs the tapped portion of light away from a base, upon which the waveguides are positioned, towards a light sensor.

Hsu et al state that "*the transition from the primary waveguide to the tap waveguide 12 is often a source of polarization-dependent loss (PDL)*", and that this PDL can be compensated by: i) a suitably designed *reflection layer* in the direction changing region, and ii) adding a suitably configured *light absorbing medium* adjacent to the tap waveguide "*so as to absorb the T_E polarity mode more than the T_M polarity mode*". Hsu et al also state that both the reflection layer and the light absorbing medium are, in fact, metal layers (see col. 6, lines 43,44, and col.12, lines 28-30 of Hsu et al).

Namely, Hsu et al disclose a waveguide tap having a first, or primary, waveguide and a second, or tap waveguide, with a transition therebetween having PDL, and a means to compensate for such PDL. However, the PDL compensating means of Hsu et al are <u>different</u> from those of claims 1-9. In particular, Hsu et al do not teach or suggest *a bend portion that has PDL properties that are opposite to the upstream waveguide, so as to compensate the PDL* associated with the coupling portion of the second, or tap, waveguide.

Although Hsu et al perceive a need to compensate the PDL associated with the transition between the primary and tap waveguides, their scheme, like other prior art techniques dealing with optical taps, fails to recognize that the PDL problem can be compensated in a relatively simple manner, by incorporating into the tap waveguide structure a pre-determined bend that introduces an opposite polarization-dependent loss therethrough, and thereby compensates for the polarization loss through the coupling portion.

Namely, the current prior art in the field of optical taps discloses other, more complex, means to compensate the PDL that arises from optical coupling, such as adding absorbing and/or reflecting metal layers to the waveguide structure (Hsu et al), or adding

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a second coupler (e.g., the US Patent to Henry et al 5,539,850, cited in paragraph [11] of the present specification). Although these prior-art solutions appear to perform their intended functions, they are either significantly more bulky, or significantly more technologically demanding to implement than the pre-determined waveguide bend of the present invention.

For example, implementing the absorbing layers of Hsu et al requires additional metal deposition and patterning processing steps to fabricate the device, which negatively impacts manufacturing time, cost and yield.

The article to **Rajarajan et al** discloses that PDL <u>within a bend</u> in a ridge waveguide can be effectively eliminated by adjusting waveguide parameters, such as the bend's ridge width, so as to make the <u>bend itself</u> polarization-independent. Rajarajan et al do not disclose or suggest using adding a waveguide bend, that has PDL opposite to an upstream waveguide of a waveguide tap, for the purpose of compensating for PDL in that upstream waveguide. The focus of Rajarajan et al is <u>on making a bend, per se</u>, polarization-independent.

Moreover, nowhere in their article do Rajarajan et al teach, disclose or suggest that a waveguide bend, that has been rendered polarization-independent using their technique, will <u>compensate</u> the PDL of waveguide taps, couplers or any other optical elements. In fact, such a polarization-independent bend cannot provide such compensation, since there is no (opposite or compensating) polarization-dependent loss through a bend that has been rendered polarization-independent. Instead, the light exiting such a polarization-independent bend will have the same polarization-dependent loss as when entering the bend, so that the PDL is not compensated by the bend.

Thus, neither Hsu et al, nor Rajarajan et al teach, disclose or suggest the incorporation of a pre-determined waveguide bend having an opposite PDL to that of the coupling portion of a waveguide tap device, to compensate for a PDL that occurs in the coupling portion of the waveguide tap.

The statement in the outstanding rejection that "*it would have been obvious to one having ordinary skill in the art at the time the invention was made to use the teaching of Rajarajan et al of having curved waveguide in Hsu et al to compensate the polarization-dependent loss by increasing either TE or TM loss*" is inaccurate, and unsupported by either reference. As noted above, Rajarajan et al disclose making a bend, per se, polarization-independent -- not using a bend having polarization-dependent loss that is opposite to that of the upstream waveguide, to compensate for the polarization-dependent loss in the upstream waveguide.

Claims 2 and 4

The arguments put forward hereinabove with reference to claim 1 are equally applicable claims 2 and 4, which are also believed to be patentable over Hsu et el in view of Rajarajan et al.

Claim 3

Applicants have amended claim 3 to additionally specify that

i) the planar optical trunk and branch waveguides comprise "silica disposed over a silicon substrate ", and

ii) the predetermined radius of the predetermined bend in the branch waveguide is "from 2 mm to 3 mm".

Support for these added limitations can be found in paragraphs [9], [37] and [40] of the original specification.

Neither Hsu et al nor Rajarajan et al teach a waveguide bend having a predetermined bend radius between 2 mm and 3 mm for compensating the coupling imbalance between the TE and TM modes. The waveguide bends described by Rajarajan et al have much smaller bend radii between 0.1mm and 0.4mm (FIGs. 1-4), and their PDL becomes negligibly small, when the bend radius increases beyond about 0.3 mm (see FIG. 1 of Rajarajan et al). This is because the waveguide bends of Rajarajan et al, which are formed in a GaAs/AlGaAs material system, have a high index contrast between the core and cladding regions; in other words – a high index delta of about 10% or more, so that both the TE and TM modes are well confined within the waveguides. Polarization properties of the GaAs/AlGaAs waveguides of Rajarajan et al are determined by so-called shape-birefringence, i.e. they depend on the waveguide shape, based on which the TE and TM modes can have different spatial distribution, so that either TE or TM modes have higher losses for low bend radius waveguides, with the TE mode being slightly less confined, and thus having a higher bend loss, if the waveguide width is not too small.

Contrary to the waveguides disclosed by Rajarajan et al, the waveguides in amended Claim 3 comprise silica on silicon. Polarization properties of such waveguides are dominated, not by the shape birefringence, but by stress, which is induced by a mismatch in thermal expansion coefficients of silica and silicon. This stress causes the TM mode in waveguides comprising silica on silicon to be substantially less confined than the TE mode. Therefore, one skilled in the art would not be compelled to use the description in Rajarajan et al to determine polarization properties of a waveguide comprising silica on silicon, since the effects described by Rajarajan et al are negligible in such waveguides.

Contrary to what is described by Rajarajan et al, applicants have found that a pre-determined bend, with a pre-determined bend radius between 2mm and 3mm, in typical silica on silicon waveguides, provides suitable imbalance in optical loss of the TE and TM modes to compensate for the coupling imbalance between said modes.

Therefore, amended claim 3 specifies features that are not taught or suggested by Hsu et al or Rajarajan et al, and is therefore believed to be patentable thereover.

New dependent Claims 5-8

New **claim 5** is dependent upon claim 1, and further specifies that the planar optical waveguide tap comprises "optical materials having mismatched thermal expansion coefficients". As described hereinabove with reference to amended claim 3, polarization properties of such waveguides are governed by stress rather than by the shape birefringence, so that Rajarajan et al is not applicable to such waveguides, and one skilled in the art would not be led to provide a pre-determined waveguide bend to compensate for a polarization-dependent loss that occurs from the coupling portion.

New **claim 6** is dependent upon new dependent claim 5, and further species that the planar optical waveguide tap comprises "silica disposed over a silicon substrate". Claim 6 is believed to be patentable over Hsu et al and Rajarajan et al, for the reasons given hereinabove with reference to claim 3 and new claim 5.

New **claim** 7 is dependent upon new dependent claim 6, and further species that the at least one predetermined bend has a radius of curvature of 2 mm to 3mm". Claim 7 is believed to be patentable over of Hsu et al and Rajarajan et al, for the reasons given hereinabove with reference to claim 3.

New **claim 8** is dependent upon claim 4, and further species that the chip defined in claim 4 comprises a silica on a silicon wafer, and that the predetermined bend has a radius of curvature of 2 mm to 3 mm". The arguments put forth hereinabove with reference to amended claim 3 are also applicable to new claim 8, which further recites features not disclosed by Hsu et al and Rajarajan et al.

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New Independent Claim 9

As noted above, **new claim** 9 defines a method for compensating for polarization-dependent loss through the coupling portion by the use of a downstream optical bend that has a polarization-dependent loss opposite to that through the coupling portion. For the reasons discussed above regarding the patentability of amended claim 1, claim 9 is also believed to be patentable over Hsu et al and Rajarajan et al.

In view of the foregoing amendments and remarks, favorable reconsideration of this application and a notice of allowance of claims 1-9 are respectfully requested.

Should any minor informalities need to be addressed, the Examiner is encouraged to contact the undersigned attorney at the telephone number listed below.

Respectfully submitted,

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CERTIFICATE OF FACSIMILE TRANSMISSION

I HEREBY CERTIFY that the foregoing correspondence has been forwarded via facsimile number **571-273-8300** to MAIL STOP AMENDMENT, COMMISSIONER FOR PATENTS, this 19 day of July 2006.

D. Kallemeres